J Technol Transf (2010) 35:637–650
DOI 10.1007/s10961-009-9140-4

Informal university technology transfer: a comparison between the United States and Germany

Christoph Grimpe · Heide Fier

Published online: 17 September 2009

Abstract Existing literature has confined university technology transfer almost exclusively to formal mechanisms, like patents, licenses or royalty agreements. Relatively little is known about informal technology transfer that is based upon interactions between university scientists and industry personnel. Moreover, most studies are limited to the United States, where the Bayh-Dole Act has shaped the institutional environment since 1980. In this paper, we provide a comparative study between the United States and Germany where the equivalent of the Bayh-Dole Act has come into force only in 2002. Based on a sample of more than 800 university scientists, our results show similar relationships for the United States and Germany. Faculty quality which is however based on patent applications rather than publications serves as a major predictor for informal technology transfer activities. Hence, unless universities change their incentives (e.g., patenting as one criterion for promotion and tenure) knowledge will continue to flow out the backdoor.

Keywords Informal university technology transfer · Cross-country comparison

JEL Classification J61 · O33

1 Introduction

Knowledge produced in the public sector has frequently been shown to be an important ingredient of economic growth and technological change (Jaffe 1989; Adams 1990; Link and Siegel 2007). In this respect, patterns of evidence for university technology transfer

C. Grimpe (✉) · H. Fier
ZEW Centre for European Economic Research, P.O. Box 10 34 43, 68034 Mannheim, Germany
e-mail: grimpe@zew.de

C. Grimpe
Katholieke Universiteit Leuven, Leuven, Belgium

C. Grimpe
University of Zurich, Zurich, Switzerland

focus on the institutions (e.g., technology transfer offices), the agents involved in technology commercialization, academic spin-offs, university-industry cooperative research centers or science parks, and incubators (Bozeman 2000; Aerts et al. 2007; Rothaermel et al. 2007). Most of the existing research puts emphasis on formal university technology transfer mechanisms (i.e., those that embody or directly lead to a legal instrument like a patent, license or royalty agreement (Bozeman 2000; Feldman et al. 2002; Thursby and Thursby 2002; Siegel and Phan 2005)). Few authors have investigated informal university technology transfer mechanisms (e.g., Link et al. 2007). Informal technology transfer focuses primarily on interactions of the agents involved (i.e., on university scientists and industry personnel) where property rights are of secondary importance.[1] Link et al. (2007) conceive informal technology transfer as a mechanism through which technology knowledge flows between the agents, for example by technical assistance or consulting. While formal technology transfer mechanisms frequently aim at transferring a research result like a patent or a license to use a technology, informal mechanisms do not, and there is usually no expectation that they will. In this sense, formal technology transfer is seen as a mechanism to allocate property rights whereas informal technology transfer is much more about informal communication processes. Examples could be contacts between academics and industry personnel at conferences, joint publications, academic consulting, or other informal contacts, talks and meetings.

However, Siegel et al. (2003) and Thursby et al. (2007) find that many university scientists in the United States do not disclose their inventions to their university although prescribed by law. And even if university inventions are publicly disclosed some firms will try to approach scientists and arrange to work with them directly (Hall et al. 2003). Hence, informal technology transfer seems to be a dominant mode of collaboration. Link et al. (2007) find that 52% of the scientists they addressed through the Research Value Mapping Program Survey of Academic Researchers had some kind of working relationship with industry personnel. Formal and informal technology transfer cannot always be easily isolated from each other as collaborative research or consulting could comprise patents being transferred from university to industry. In fact, existing literature suggests that formal and informal technology transfer may go well together (Siegel et al. 2003; Link et al. 2007) in that informal contacts improve the quality of a formal relationship or that formal contracts are accompanied by an informal relation of mutual exchange on technology-related aspects. Grimpe and Hussinger (2008) find that both channels are complementary (i.e., using one channel of collaboration if the other one is in place has a higher incremental impact on the innovation performance of firms than using one of the two channels more intense in isolation). It is therefore not surprising that formal and informal technology transfer may occur simultaneously (Perkmann and Walsh 2007) and that firms have an interest to make use of both.

Taking these findings together suggests that university administrators will have an interest to better understand the determinants of informal technology transfer given their objective to create revenues for the university. In the United States, the commercialization of technology developed by university scientists had been spurred by the enactment of the Bayh-Dole Act in 1980. In other countries like Germany, an equivalent to the Bayh-Dole Act only came into force 20 years later in 2002. The scientists' right to commercialize inventions privately before 2002 is still reflected by a rather low number of German university patents (Czarnitzki et al. 2007, 2008) and few licensing agreements (Grimpe and

[1] In the following, we will use the term 'university scientist' as shorthand for scientists employed at universities or other public research institutes.

Hussinger 2008) compared to the United States. Hence, the purpose of this paper is to shed light on the effects that institutional differences might have on the choice of scientists to transfer technology informally. We present comparative findings for Germany by using the approach of Link et al. (2007). Moreover, we extend their previous findings by focusing on two neglected factors more explicitly: the scientist's individual productivity as well as the research environment in which the informal technology transfer takes place. Using a comprehensive sample of more than 800 German university scientists, we explore the determinants of informal technology transfer and derive implications for university administrators and policy makers.

The remainder of the paper is organized as follows: The next section first provides a brief review of the literature on university technology transfer. We then describe the results of the pioneering study on informal technology transfer in the United States (Link et al. 2007) and outline what might be expected in the German context. Section 3 explains our empirical methods before the subsequent section will show the results. We conclude the paper with a brief summary statement.

2 Literature background and theoretical considerations

Literature has identified two major sources of motivation for university scientists: the first has been described as recognition within the academic community. Recognition can most prominently be achieved through publications, patent applications, presentations, and the awarding of research grants. As tenure decisions and promotions are primarily a function of recognition in its various forms, untenured faculty members will have strong incentives to pursue these objectives. Second, faculty members may also be motivated by the opportunity to acquire additional resources, resulting either in personal financial gain or in funding available for a build-up of physical and human capital at the scientist's institution (Link et al. 2007). Analyzing the effectiveness of university technology transfer offices (TTOs) which were created mainly as a consequence of the Bayh-Dole Act assigning the rights on faculty inventions to the university, Siegel et al. (2003, 2004) find, however, that these TTOs provide little incentives for faculty involvement. In other words, university TTOs loose opportunities for technology commercialization due to a perceived unfavorable royalty distribution to the scientist. In fact, simply increasing the returns to faculty members seems to make the commercialization process more effective (Friedman and Silberman 2003; Lach and Schankerman 2004; Link and Siegel 2005). However, significant difficulties in negotiating and transacting with the TTO remain (Link and Siegel 2005) which suggests that university scientists may have strong incentives to informally transfer their research results instead of choosing the route through the TTO.

Link et al. (2007) have been the first to shed further light on the decision of academics to engage in informal technology transfer. Their results for the United States are based on the Research Value Mapping Program Survey of Academic Researchers for which a sample of university scientists and engineers with a Ph.D. at the 150 Carnegie Extensive Doctoral/Research Universities during the time period spring 2004 to spring 2005 was collected. Link et al. (2007) distinguish between three mechanism through which informal technology transfer may occur: commercializing technology through direct collaboration with industry personnel, joint publication with industry personnel, and serving as a formally paid consultant to an industrial firm. They link these choices to a number of variables depicting faculty characteristics, including gender, tenure/years with tenure, age, and the percent of time spent on grants-related research. While gender serves as a control variable, the tenure variables are intended to measure faculty quality in terms of received recognition and research success. These measures are based on the argument that tenure serves as a signal and that more credentialed faculty will also be in higher demand by industry (Murray 2004). Age is included to disentangle the effects from tenure as a signal of faculty quality and the time necessary to build up relationships with industry. The percent of time allocated to grants-related research serves as another proxy for human capital as the awarding of grants involves a review process by an external organization, and only the most promising grant applications will presumably be likely to pass this hurdle. Finally, academic disciplines control for different technological and hence transfer opportunities.

Their results show that 52% of the scientists had some kind of working relationship with industry personnel, including most prominently consulting (18%), joint commercialization of technology (15.8%), and joint publication activities (14.6%). Regarding their faculty quality indicators they show that tenured academics are more likely than untenured academics to engage in all three informal technology transfer activities. Consistent with this finding, the number of years with tenure as an alternative measure increases the propensity for informal technology transfer. Moreover, they observe the same effect for the percentage of time spent on grants-related research. Regarding the gender, male faculty members are found to be more likely to transfer technology informally than female faculty members. Although Link et al. (2007) control for disciplinary effects, they argue that gender effects might also be explained by disciplinary selection in that women are typically less represented in disciplines most active in technology transfer. Regarding the scientist's age, they find that younger academics are more likely to engage in joint commercialization of technology. There is no effect on the other two forms of informal technology transfer. In sum, the results by Link et al. (2007) provide first insights into the decision of academics to engage in informal technology transfer. There are, however, a number of reasons which suggest that results on the propensity to engage in informal technology transfer could be different in different institutional contexts. In the following, we will thus provide arguments that point to the differences between the United States and Germany with a possible influence on the academic's choice for engaging in informal technology transfer.

Differences can, first of all, be attributed to the existence of the Bayh-Dole Act in the United States since 1980. In Germany, the 'professor's privilege' ('Hochschullehrer-Privileg') was in place until 2002. Based on Article 5 of the German constitution, which focuses on the freedom of science and research, the professor's privilege entitled academics in Germany to use their scientific results for private commercialization even if the underlying research was carried out at and financed by the university or other public sources (Kilger and Bartenbach 2002). In fact, the professors' right to commercialize inventions privately before that year is reflected by a low number of German university patents (Czarnitzki et al. 2007, 2008). Moreover, university licensing which is receiving much attention in the literature on industry-science links is used by relatively few German firms (Grimpe and Hussinger 2008). Instead, consulting and informal collaboration have been shown to be substantial. Although several years have passed since the abolishment of the professor's privilege in Germany, we can expect these patterns to persist, particularly because most German universities are still in the process to set up an effective technology transfer infrastructure. As a consequence, university scientists in Germany, and especially highly credentialed faculty members, should be more likely to engage in informal technology transfer than their U.S. counterparts.

Second, differences between the United States and Germany could arise from different work contracts. While U.S. faculty members receive their pay typically only for 9 months of the year, German academics are paid for 12 months. The missing 3 months could in turn motivate U.S. faculty to seek other income opportunities and to engage in informal technology transfer. Moreover, U.S. faculty might be under higher pressure than their German colleagues to acquire research money to support ongoing projects and junior staff.

Third, we may assume that the specific German orientation toward excellence in engineering plays a role for the informal technology transfer behavior. Several German universities have a long-standing tradition and reputation in the field of engineering. Engineering research is organized in large research groups, with multi-million research funding and close collaboration with industry. Moreover, engineers in Germany are typically member of the German engineers association ('VDI—Verein Deutscher Ingenieure'). Both the bonds through their alma mater and the network provided by the engineering association should therefore facilitate informal technology transfer activities. As a result, we should be able to observe strong positive effects particularly from scientists in engineering disciplines.

Besides the alleged differences between the United States and Germany, our research also aims at extending the findings of Link et al. (2007) by focusing more in detail on the faculty quality dimension as well as on the scientist's research environment. While the faculty quality indicators used by Link et al. (2007) are presumably correlated with individual productivity, they do not account for the different facets of productivity upon which tenure and grant award decisions are typically based. We have outlined above that academic prestige serves as a signal to potential commercialization partners in industry. Prestige can in turn be built up through publications or patents. Recent studies for the United States and Germany show that publications and university patenting are positively linked (e.g., Agrawal and Henderson 2002; Stephan et al. 2006; Czarnitzki et al. 2009). As a consequence, we will include direct measures of the publication and patenting activities of scientists and relate them to their informal technology transfer behavior. More specifically, we expect positive effects from publications on the decision to jointly publish with industry personnel and from patents on the informal commercialization of technology. Regarding consulting, we expect positive effects from both publications and patenting.

Besides research productivity, tenure and the awarding of grants, there is another aspect of faculty quality that has been neglected so far (i.e., whether the scientist is a research group leader). Obviously, leading a research group should be associated with some academic prestige developed through publications or patents. Moreover, being a research group leader should lead to a multitude of contacts with industry personnel at various occasions. Assuming that the group leader's recognition increases with group size, there should be an incentive to engage in informal technology transfer and acquire research money to support the group. Effects should be particularly pronounced for the decision to commercialize technology and to serve as a paid consultant as these forms of technology transfer could serve as a mechanism to raise funding.

As a final extension to the model by Link et al. (2007) we suggest that the scientist's research environment matters for the decision to transfer technology informally. In this context, Etzkowitz (2003) has put forward the notion of research groups as 'quasi-firms' in entrepreneurial universities. Provided that research funding is awarded on a competitive basis, research groups will presumably exhibit firm-like qualities. In the following, we will focus on one aspect of the research environment which is the size of the peer group at the scientist's institution. On the one hand, the more people are working on similar topics the more internal opportunities for collaboration arise. On the other hand, competitive pressure for research money will also be higher which is why we expect academics to be more likely to engage in informal technology transfer.

3 Data and econometric model

The data used in our empirical analysis stem from a survey among German scientists which was carried out on behalf of the German Federal Ministry of Education and Research. The aim of the survey, which was part of an evaluation project of the 6th European Union Research Framework Program, was to get an overview of university scientists' efforts to acquire research grants from various sources. Data were collected in 2008 using an online survey instrument. On the one hand, contacting respondents via e-mail involves the risk of not reaching a considerable number of persons due to outdated or misspelled e-mail addresses. On the other hand, e-mails have the advantage to be independent from space (i.e., the e-mail will reach the scientist although she or he might be away from the home office). Two major data sources were used for the sampling procedure. In a first step, the population of scientists employed at German universities was derived from the 'Hochschullehrerverzeichnis' from the year 2006. The 'Hochschullehrerverzeichnis' is a database containing the names, degrees, and contact information of the academic personnel holding a Ph.D. and being employed at German universities.[2] In a second step, scientists at government-funded public research institutes were identified via an internet search of the institutes' websites. These research institutes belong to one of the four large German science organizations: Max Planck Society, Fraunhofer Society, Leibniz Association and Helmholtz Association. In total, 20,519 scientists with available e-mail addresses were identified. For 4,250 scientists, delivery of the message failed because of a wrong e-mail address. We obtained 2,797 responses, a response rate on the net sample of 17.2% which can be regarded as satisfactory for such a large-scale online survey. Due to missing values for some variables the actual number of observations available for analysis is, however, lower.

The measures of informal technology transfer and the explanatory variables are based on faculty responses. To achieve comparability, we used exactly the same questions as in the Research Value Mapping Program Survey of Academic Researchers (Link et al. 2007). For our dependent variables relating to alternative mechanisms of informal technology transfer, scientists were asked to respond to these statements in the survey:

During the past 12 months:

- I worked directly with industry personnel in an effort to transfer or commercialize technology or applied research.
- I co-authored a paper with industry personnel that has been published in a journal or refereed proceedings.
- I served as a formal paid consultant to an industrial firm.

We estimate several probit models and regress the three choices to transfer technology informally on different sets of explanatory variables. The first set is intended to exactly replicate the analysis by Link et al. (2007) for Germany, thus including faculty characteristics like gender (males $= 1, 0$ otherwise), tenure (tenured $= 1, 0$ otherwise), age (in logs),[3] pre-eminence of the faculty member, as measured by the percent of time spent on grants-related research, and dummies for the scientific disciplines (social sciences and humanities, life sciences, other natural sciences, engineering sciences, with social sciences and humanities being the reference case). As an alternative specification, we include a scientist's number of years with tenure (in logs), leaving tenure and age out of the model due to high correlation.

[2] This excludes the so-called 'universities of applied sciences' whose major task is teaching and not research.

[3] For all variables which enter the regression in logs, a value of 0 was replaced by 0.1 to prevent missing values due to the log transformation.

The second set of variables is our extension to the model used by Link et al. (2007). The survey of German scientists provides more in-depth information about the scientist's productivity and the institutional environment in which the research activities are carried out. Scientists were asked whether they are leading a research group (leader = 1, 0 otherwise) and how many publications in refereed journals and patent applications they were able to achieve in the period from 2002 to 2006 (each entered in logs). To control for the research environment and, more specifically for the size of the peer group, scientists were asked how many colleagues they have at their institution working on similar research topics (in logs).

4 Results

4.1 Descriptive statistics

The descriptive statistics (Table 1) show that almost half of the surveyed scientists worked together with industry personnel in an effort to commercialize technology. Slightly more than 20% of the scientists exhibit at least one joint publication with industry personnel. Around 17% of the scientists served as a formally paid consultant to a firm. Regarding the faculty characteristics we find that the majority of the surveyed scientists are male (86%) with an average age 49 years. A high share of the scientists in our sample is tenured (83%) and on average the scientists have been tenured since 12 years. Further, the surveyed researchers spent about one-third of the time on grants-related research. Regarding the scientific disciplines, our sample is rather evenly split between the four categories.

If we compare the descriptive statistics for the sample of German scientists with the descriptive statistics of the sample used by Link et al. (2007) we can observe considerable differences. Apparently, German scientists are more active in commercializing technology than their U.S. colleagues but somewhat less active in joint publication and consulting

Table 1 Descriptive statistics

Variable	Obs.	Mean	Std. dev.	Min.	Max.
Commercialize technology	945	0.438	0.496	0	1
Joint publication	938	0.230	0.421	0	1
Consulting	925	0.172	0.377	0	1
Gender	943	0.856	0.351	0	1
Tenure	926	0.828	0.377	0	1
Percent time spent on grants-related research	880	32.378	22.867	0	100
Age	948	49.283	8.371	28	70
Years with tenure	745	11.913	8.391	1	43
Social sciences and humanities	929	0.212	0.409	0	1
Life sciences	929	0.284	0.451	0	1
Other natural sciences	929	0.302	0.460	0	1
Engineering sciences	929	0.201	0.401	0	1
Research group leader	928	0.706	0.456	0	1
No of publications	948	20.638	26.440	0	200
No of patent applications	948	0.714	1.927	0	24
Size of the peer group at the scientist's institution	948	30.324	76.077	0	1000

Sample restricted to scientists with non-missing values for at least one informal technology transfer channel activities. At the same time the U.S. sample is more balanced regarding the gender of the scientists compared to the sample of the German scientists which results from gender stratification. The descriptive statistics for the additional variables which were not available in the U.S. sample show that about 70% of the scientists in our sample stated that they were research group leaders at the time when the survey was conducted. The productivity variables reveal that the surveyed scientists published around 20 articles in refereed journals within a 5-year period and on average applied for 0.7 patents during the years 2002–2006. Finally the variable that controls for the size of the peer group shows that on average the size of the peer group at the scientist's institution is about 30 scientists.

4.2 Probit regressions

Table 2 presents the results of probit regression models. For each of the three dependent variables four different model specifications are estimated. Models (1) and (2) for each dependent variable show the results of the basic model following the empirical approach of Link et al. (2007). In Model (1) we include the tenure dummy and age while the years with tenure are omitted due to high correlation with age. Model (2) substitutes age by years with tenure. Models (3) and (4) show the same specification as (1) and (2) but they are extended by the additional variables on productivity and research environment discussed before.

Regarding gender, Link et al. (2007) find that male academics are more likely to engage in informal technology transfer, specifically in the commercialization of technology and consulting activities. We are able to confirm this finding for the German data. It is particularly pronounced for consulting activities where the coefficient is highly significant. Moreover, we can largely confirm the positive effects from tenure on the likelihood to engage in technology commercialization and joint publication. Model (2) however shows that the number of years with tenure does not have any effect on informal technology transfer which is in stark contrast to the findings by Link et al. (2007). Similarly, age turns out to have no effect at all which is in concordance with the findings from the United States. We can again confirm the U.S. findings regarding the share of time spent on grants-related research. In both datasets, the effect is positive and significant for all three forms of informal technology transfer. To sum up, our findings for the German scientists largely confirm the results obtained by Link et al. (2007). Apart from differences in the descriptive statistics regarding the actual engagement in the three forms of informal technology transfer, the relationships between the assumed driving factors are similar, despite the institutional differences between the United States and Germany.

While in the U.S. study discipline effects were held constant and results weighted by discipline sampling proportions, the models using the German dataset include dummy variables to capture discipline effects.[4] This enables us to consider disciplinary effects more explicitly. Generally speaking, all three included disciplines are more likely to engage in informal technology transfer compared to the reference group of social sciences and humanities which is anything but surprising. Particularly engineering scientists are very likely to engage in all three forms of informal technology transfer, suggesting that there are

[4] The reason for this is that sampling proportions by field could not be taken into account as—due to the inclusion of government-funded research institutes—the population of scientists in Germany with regard to the field is not fully transparent. In Germany, a significant share of the engineering related research activities are performed by the Fraunhofer institutes in comparison to universities. The same applies to life sciences research which is to a significant extent performed at Max Planck institutes.

Table 2 Probit results

	Commercialize technology				Joint publication				Consulting			
	1	2	3	4	1	2	3	4	1	2	3	4
Gender	0.231* (0.137)	0.203 (0.162)	0.155 (0.144)	0.146 (0.171)	0.298* (0.170)	0.222 (0.195)	0.213 (0.177)	0.135 (0.203)	0.632*** (0.194)	0.782*** (0.245)	0.647*** (0.200)	0.819*** (0.254)
Tenure	0.349** (0.144)		0.214 (0.155)		0.394** (0.168)		0.299* (0.177)		0.087 (0.171)		−0.027 (0.179)	
Years with tenure (in logs)		−0.02 (0.065)		−0.013 (0.068)		0.001 (0.071)		0.021 (0.074)		0.047 (0.077)		0.076 (0.080)
Percent time grants-related research	0.005** (0.002)	0.005* (0.003)	0.005** (0.002)	0.004 (0.003)	0.005** (0.002)	0.006** (0.003)	0.005* (0.002)	0.006* (0.003)	0.004 (0.003)	0.005 (0.003)	0.004* (0.003)	0.006* (0.003)
Age (in logs)	0.038 (0.310)		−0.018 (0.332)		0.217 (0.337)		0.098 (0.353)		0.379 (0.358)		0.266 (0.367)	
Life sciences	0.472*** (0.135)	0.474*** (0.153)	0.211 (0.152)	0.211 (0.171)	0.389** (0.169)	0.483** (0.195)	0.128 (0.187)	0.227 (0.215)	0.469*** (0.162)	0.558*** (0.187)	0.406** (0.178)	0.499** (0.207)
Other natural sciences	0.287** (0.133)	0.233 (0.148)	0.147 (0.146)	0.074 (0.162)	0.514*** (0.163)	0.597*** (0.186)	0.360** (0.177)	0.451** (0.202)	−0.13 (0.172)	−0.131 (0.193)	−0.143 (0.183)	−0.134 (0.210)
Engineering sciences	1.365*** (0.155)	1.372*** (0.169)	1.007*** (0.164)	1.009*** (0.179)	1.123*** (0.172)	1.253*** (0.193)	0.897*** (0.184)	1.060*** (0.205)	0.585*** (0.171)	0.611*** (0.191)	0.478*** (0.182)	0.549*** (0.204)
Research group leader			0.415*** (0.118)	0.378*** (0.133)			0.138 (0.131)	0.203 (0.149)			0.403*** (0.145)	0.440*** (0.170)
Size of the peer group at the scientist's institution (in logs)			0.048 (0.036)	0.066* (0.040)			−0.045 (0.040)	−0.049 (0.044)			−0.093** (0.043)	−0.134*** (0.048)

Table 2 continued

	Commercialize technology				Joint publication				Consulting			
	1	2	3	4	1	2	3	4	1	2	3	4
No of publications (in logs)			−0.096** (0.043)	−0.069 (0.047)			0.069 (0.047)	0.076 (0.050)			−0.036 (0.049)	0.004 (0.054)
No of patent applications (in logs)			0.795*** (0.101)	0.733*** (0.108)			0.521*** (0.084)	0.488*** (0.090)			0.304*** (0.087)	0.274*** (0.094)
Constant	−1.443 (1.162)	−0.863*** (0.235)	−1.239 (1.250)	−1.091*** (0.271)	−2.903** (1.269)	−1.719*** (0.291)	−2.454* (1.333)	−1.926*** (0.323)	−3.428** (1.357)	−2.168*** (0.341)	−2.975** (1.397)	−2.400*** (0.381)
Pseudo R^2	0.115	0.114	0.195	0.188	0.095	0.095	0.149	0.153	0.069	0.077	0.104	0.118
N	835	668	821	657	828	661	814	650	821	655	808	645
LR Chi^2	131.399	104.918	219.089	170.786	84.423	70.369	129.368	110.718	52.072	47.992	77.657	72.903
P-value	0	0	0	0	0	0	0	0	0	0	0	0

* $P < 0.10$, ** $P < 0.05$, *** $P < 0.01$; Social sciences and humanities serve as reference group. Robust standard errors in parentheses

indeed strong informal ties between academics and industry personnel, for example through the German engineers association. There is no effect on consulting for other natural scientists.

Turning to the extension of the baseline models, we find several interesting effects. Apparently, being a research group leader matters considerably for technology commercialization and consulting but not for joint publication. This finding confirms our theoretical reasoning that research group leaders have a higher incentive to acquire research money in order to finance their group. In this light, joint publication activities seem inappropriate. Moreover, research group leaders are often caught in administrative business and therefore often do not find the time to conduct research and publish the results. Our measure for the research environment (i.e., the size of the peer group) turns out to be marginally positively related to technology commercialization and negatively to consulting. We expected a positive sign throughout due to the argument that research funding is awarded on a competitive basis and the size of the peer group should positively influence the level of competition for funds. We may speculate that the negative sign for consulting hints at a different kind of peer pressure not to engage too intensively in activities that do not primarily benefit the university or research institute but rather the private remuneration.

Finally, focusing on the research productivity indicators publications and patent applications we find that the number of publications is not important at all for the decision to engage in any form of informal technology transfer. Instead, patent applications have a consistently positive and significant effect. Obviously, scientists succeed in signalling their quality to industry not by publications which would rather contribute to academic merits but by patents. Firms seem to acknowledge the practice-oriented work of the scientists that may be immediately integrated into the firm's knowledge base. In this respect, our results are in contrast to previous findings for the biotechnology industry showing that university "star" scientists, measured in terms of publication activity, are attractive partners for firm scientists to collaborate with (e.g., Zucker and Darby 1996; Zucker et al. 2002). Hence, this argument seems to hold true only in the specific disciplinary setting of biotechnology while it disappears when scientists from various disciplines are considered.

Comparing the baseline models (1) and (2) with our extended models (3) and (4) shows that the positive tenure effect as a proxy for faculty quality observed both in the U.S. and German data is partly taken over by the patent and research group leader variables. Faculty quality hence seems to be a multifaceted construct on which the added variables were able to shed some more light.

5 Conclusion

The purpose of this paper was to shed light on the effects that institutional differences have on the choice of scientists to transfer technology informally. Our comparison of results for the United States and for Germany reveals similar behavior of faculty. Focusing in more detail on the research productivity of faculty in terms of publications and patents our results show that particularly university scientists with a track record of patent applications are an attractive partner for firm scientists in joint informal technology transfer activities.

The lesson learned from our research is simple; faculty, like all economic agents, respond to incentives and until universities change their incentives (e.g., patenting as one criterion for promotion and tenure) knowledge will continue to flow out the backdoor.

Acknowledgments We thank Albert N. Link, Donald S. Siegel, the participants at the 2007 Technology Transfer Society Conference in Palm Desert, and Christian Rammer for helpful comments on earlier versions of this paper.

Appendix

See Table 3.

Table 3 Correlations

	1	2	3	4	5	6	7	8	9	10	11
1. Gender	1.000										
2. Tenure	0.167	1.000									
3. Percent time spent on grants-related research	−0.021	−0.237	1.000								
4. Age (in logs)	0.121	0.479	−0.171	1.000							
5. Life sciences	−0.116	−0.080	0.075	0.034	1.000						
6. Other natural sciences	0.106	0.009	−0.027	−0.022	−0.424	1.000					
7. Engineering sciences	0.121	0.120	0.090	0.002	−0.310	−0.339	1.000				
8. Research group leader	0.092	0.239	−0.016	0.152	0.073	−0.052	0.015	1.000			
9. No of publications (in logs)	0.131	0.039	0.020	0.057	0.238	0.175	−0.245	0.294	1.000		
10. No of patent applications (in logs)	0.097	0.081	0.064	0.067	0.072	−0.048	0.221	0.147	0.128	1.000	
11. Size of the peer group at the scientist's institution (in logs)	0.121	−0.034	0.120	−0.091	0.074	0.089	0.047	0.030	0.078	0.155	1.000
Variance inflation factor (mean = 1.42)	1.11	1.45	1.11	1.34	2.00	1.99	1.85	1.19	1.34	1.15	1.10

Sample restricted to scientists with non-missing values for at least one informal technology transfer channel

References

Adams, J. D. (1990). Fundamental stocks of knowledge and productivity growth. *Journal of Political Economy, 98*, 673–702.

Aerts, K., Matthyssens, P., & Vandenbempt, K. (2007). Critical role and screening practices of European business incubators. *Technovation, 27*, 254–267.

Agrawal, A., & Henderson, R. (2002). Putting patents in context: Exploring knowledge transfer from mit. *Management Science, 48*(1), 44–60.

Bozeman, B. (2000). Technology transfer and public policy: A review of research and theory. *Research Policy, 29*, 627–655.

Czarnitzki, D., Hussinger, K., & Schneider, C. (2008). *Commercializing academic research: The quality of faculty patenting*, ZEW Discussion Paper No. 08-069, Mannheim.

Czarnitzki, D., Glänzel, W., & Hussinger, K. (2007). Patent and publication activities of German professors: An empirical assessment of their co-activity. *Research Evaluation, 16*(4), 311–319.

Czarnitzki, D., Glänzel, W., & Hussinger, K. (2009). Heterogeneity of patenting activity and its implications for scientific research. *Research Policy, 38*, 26–34.

Etzkowitz, H. (2003). Research groups as 'Quasi-Firms': The invention of the Entrepreneurial University. *Research Policy, 32*, 109–121.

Feldman, M. P., Feller, I., Bercovitz, J., & Burton, R. (2002). Equity and the technology transfer strategies of American research universities. *Management Science, 48*, 105–121.

Friedman, J., & Silberman, J. (2003). University technology transfer: Do incentives, management, and location matter? *Journal of Technology Transfer, 28*, 81–85.

Grimpe, C., & Hussinger, K. (2008). *Formal and informal technology transfer from academia to industry: complementarity effects and innovation performance*, ZEW Discussion Paper No. 08-080, Mannheim.

Hall, B. H., Link, A. N., & Scott, J. T. (2003). Universities as research partners. *Journal of Economic Studies, 85*, 485–491.

Jaffe, A. (1989). The real effects of academic research. *American Economic Review, 97*(5), 957–970.

Kilger, C., & Bartenbach, K. (2002). New rules for German professors. *Science, 298*(8), 1173–1175.

Lach, S., & Schankerman, M. (2004). Royalty sharing and technology licensing in universities. *Journal of the European Economic Association, 2*, 252–264.

Link, A. N., & Siegel, D. S. (2005). Generating science-based growth: An econometric analysis of the impact of organizational incentives on university–industry technology transfer. *European Journal of Finance, 11*, 169–182.

Link, A. N., & Siegel, D. S. (2007). *Innovation, entrepreneurship, and technological change*. Oxford: Oxford University Press.

Link, A. N., Siegel, D. S., & Bozeman, B. (2007). An empirical analysis of the propensity of academics to engage in informal university technology transfer. *Industrial and Corporate Change, 16*(4), 641–655.

Murray, F. (2004). The role of academic inventors in entrepreneurial firms: Sharing the laboratory life. *Research Policy, 33*, 643–659.

Perkmann, M., & Walsh, K. (2007). University-industry relationships and open innovation: Towards a research agenda. *International Journal of Management Reviews, 9*(4), 259–280.

Rothaermel, F. T., Agung, S. D., & Jiang, L. (2007). University entrepreneurship: A taxonomy of the literature. *Industrial and Corporate Change, 16*(4), 691–791.

Siegel, D. S., & Phan, P. (2005). Analyzing the effectiveness of university technology transfer: Implications for entrepreneurship education. In: G. Liebcap (Ed.), *Advances in the study of entrepreneurship, innovation, and economic growth* (pp. 1–38). Amsterdam.

Siegel, D. S., Waldman, D. A., Atwater, L. E., & Link, A. N. (2004). Toward a model of the effective transfer of scientific knowledge from academicians to practitioners: Qualitative evidence from the commercialization of university technologies. *Journal of Engineering and Technology Management, 21*(1–2), 115–142.

Siegel, D. S., Waldman, D., & Link, A. (2003). Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: An exploratory study. *Research Policy, 32*, 27–48.

Stephan, P. E., Gurmu, S., Sumell, A. J., & Black, G. (2006). Who's patenting in the university? *Economics of Innovation and New Technology, 16*(2), 71–99.

Thursby, J. G., Fuller, A., & Thursby, M. C. (2007). US faculty patenting: Inside and outside the university. *Research Policy, 38*, 14–25.

Thursby, J. G., & Thursby, M. C. (2002). Who is selling the ivory tower? Sources of growth in university licensing. *Management Science, 48*, 90–104.

Zucker, L. G., & Darby, M. R. (1996). Star scientists and institutional transformation: Patterns of invention and innovation in the formation of the biotechnology industry. *Proceedings of the National Academy of Sciences, 93*, 12709–12716.

Zucker, L. G., Darby, M. R., & Armstrong, J. S. (2002). Commercializing knowledge: University science, knowledge capture, and firm performance in biotechnology. *Management Science, 48*, 138–153.